

36. BASALT FROM THE COCOS PLATE, SITE 487, LEG 66: PETROLOGY AND GEOCHEMISTRY¹

J. L. Joron, Laboratoire de Géochimie comparée et systématique, Université de Paris VI, 75230 Paris, France,
and Groupe des Sciences de la Terre, Laboratoire Pierre Süe, CEN, Saclay 91191 Gif/Yvette, France

H. Bougault, Centre Océanologique de Bretagne, CNEXO, B.P. 337, 29273 Brest, France
and

R. C. Maury and J. F. Stephan, Université de Bretagne Occidentale, 29283 Brest, France

ABSTRACT

Major oxide and trace element determinations of the composition basalts from the bottom of Hole 487, together with microprobe analyses of their minerals (olivine, magnesiochromite, salite, and plagioclase), prove that they are depleted oceanic tholeiites.

LITHOLOGY

Seven meters of basalt, overlain by 150 meters of sedimentary layers, were recovered at Site 487 on the Cocos Plate at 99°09' W and 15°51' N, close to the Central America Trench off Acapulco. Three basalt samples from Section 487-20-1 (55–58 cm, 72–78 cm, and 82–89 cm) were available to us. They belong to the same magmatic unit and differ from another only in degree of alteration: the 55–58 cm interval is the freshest and the 82–89 cm interval the most altered. The petrographic features are those commonly observed in ocean floor basalts: they are subaphyric, with plagioclase phenocrysts dominant over olivine phenocrysts, and pyroxene phenocrysts are apparently absent. The groundmass is composed of abundant plagioclase microlites, associated with olivine, clinopyroxene and rare spinel microcrysts, and partly devitrified brown glass.

MAJOR ELEMENT COMPOSITION

The three analyses in Table 1 differ only by minor variations probably due to alteration: SiO₂ and the amount of the loss on ignition increase from 55–58 cm to 82–89 cm with petrographic indications of alteration. All the major element concentrations fall in the range of typical low-potassium ocean floor tholeiites. The FeO*/FeO* + MgO ratio is close to 0.5 (0.48–0.53), indicating that Site 487 basalt has not suffered extensive fractionation of olivine; the freshest sample (487-20-1, 55–58 cm) shows a slightly undersaturated character (0.12% normative nepheline).

MINERALOGY

Selected microprobe analyses are given in Table 2.

Olivines. Their composition is rather constant (Fo₈₈), without noticeable variation from the core to the rim in the phenocrysts; the smallest microlites are slightly iron-enriched (Fo₈₅).

Spinels. They are represented only by tiny octahedra of *magnesiochromite*, Cr being the dominant trivalent cation and Mg²⁺ > Fe²⁺ (Table 2, Analyses 7 to 9). This spinel composition is commonly found in basalts from midoceanic ridges and ocean floors and may be typical of slightly to moderately fractionated lavas with FeO*/FeO* + MgO ratio less than 0.57 and Cr content greater than 350 ppm (Sigurdsson and Schilling, 1976).

Clinopyroxenes. Their occurrence is restricted to the groundmass, where they are rather scarce. They are characterized by high Al₂O₃, TiO₂, and CaO content and plot into the *salite* field of the Ca-Mg-Fe diagram, usually typical of clinopyroxenes from alkali basalts; this fact must be correlated with the slightly undersaturated character of the whole rock. These salites are relatively iron-rich (Fs₁₅-Fs₂₀).

Plagioclases. The phenocrysts have a rather constant composition close to bytownite An₈₅. Core-to-rim compositional variations are of limited importance (2–5% anorthite) and predominantly of reverse type (Analyses 12–14, Table 2). The extreme peripheries of the phenocrysts and the groundmass feldspars (Analyses 15–18) are more sodic (bytownite-labradorite An_{78–68}). All the feldspars studied have low K and significant Mg contents, which appears to be characteristic of plagioclase from seafloor tholeiitic rocks (Hawkins, 1977).

Summarizing, the mineral composition Leg 66 basalt is typical of ocean floor tholeiites.

TRACE ELEMENTS

The trace element data of the three basaltic samples from Hole 487 are given in Table 3. Although they are not trace elements, the concentrations of Ti, Mn, and Fe have been converted to ppm to present all elements belonging to the first transition series in the same table. The elements are arranged in the order of increasing atomic number. All concentrations were determined by X-ray spectrometry (XRF) up to Nb, except Sc, which was determined by neutron activation analysis (NA), and Co and Ni, for which both XRF and Na data are available; from Sb to U all concentrations were obtained by Na.

¹ Initial Reports of the Deep Sea Drilling Project, Volume 66.

Table 1. Basalt from Hole 487: Major elements and C.I.P.W. norms.

Sample (interval in cm)	487-20-1 55-58	487-20-1 72-78	487-20-1 82-89
SiO ₂	48.72	48.83	49.99
TiO ₂	0.84	0.86	0.84
Al ₂ O ₃	16.33	16.72	16.68
Fe ₂ O ₃	9.58	9.98	9.24
MnO	0.14	0.16	0.14
MgO	9.40	8.04	8.14
CaO	13.24	13.44	13.33
Na ₂ O	2.45	1.65	2.05
K ₂ O	0.09	0.18	0.14
P ₂ O ₅	0.08	0.11	0.09
Total	100.87	99.97	100.64
Loss on ignition 1050°C	0.51	0.62	1.15
Loss on ignition 1050°C	0.01	0.53	0.86
Or	0.53	1.07	0.83
ab	20.49	14.08	17.36
an	33.28	38.02	35.95
ne	0.12		
di { wo	13.29	11.90	12.39
{ en	8.43	7.13	7.64
{ fs	4.01	4.15	4.03
en		10.48	9.40
Fs		6.10	4.97
Fo	10.48	1.81	2.28
Fa	5.50	1.16	1.33
mt	2.09	2.19	2.02
il	1.59	1.65	1.60
ap	0.19	0.26	0.21
S.I.	45.4	42.3	43.3
D.I.	21.1	15.2	18.2

Note: The norms are calculated with 85% of total iron as FeO and 15% as Fe₂O₃ (total Fe analysis is given as Fe₂O₃).

These data show the three samples to be very similar to one another and to be part of the same basaltic unit. This is not surprising, considering the restricted depth interval from which they were selected—Core 20-1, 55–89 cm); only the three alkali elements show significant differences: K₂O (in Table 1)—0.09%, 0.18%, 0.14%; Rb—0.4 ppm, 4.9 ppm, 3.1 ppm; Cs—0.02 ppm, 0.18 ppm, 0.12 ppm. These well-correlated variations are not considered primary features of lavas but due to alteration processes. That concentrations of trace elements are within a homogeneous unit constant except for those of alkali metals has already been observed—for instance in Hole 395A, which showed slight alteration (Bougault et al., 1978; Bougault, Joron, and Treuil, 1979), and in holes at Sites 417–418, which showed strong alteration (Joron et al., 1979; Bougault, Cambon, et al., 1979). Our results, relative to well-preserved material, show once more that alkali metals have to be analyzed very carefully in any attempt to determine oceanic tholeiite genesis, since only slight alteration of material considered to be fresh (based on ignition loss and thin section observations) can modify Rb and Cs concentrations by a factor of 10.

The high partition coefficient elements Cr and Ni mirror the crystallization of ferromagnesian minerals

from basaltic liquid; Cr and Ni concentrations vary, respectively, from 600 and 250 ppm, in primary liquids to 50 and 50 ppm, in differentiated liquids in oceanic tholeiites (Bougault et al., 1979). In this respect, the lavas in Hole 487 underwent moderate fractional crystallization.

The hygromagmaphile elements of transition series 1, 2, 3, and 4, all showing ions with an electronic structure of rare gas (except V), are plotted in an extended “rare earth diagram” (Bougault and Treuil, 1980) in Figure 1. The first significant feature of this basalt is its “depleted” character, normalized concentrations of the most hygromagmaphile elements (Th, Ta, Nb, and La) being much lower than others. The second concerns the normalized Ta/La (or Nb/La) ratio, which seems to be lower than 0.5. A precise value of this normalized Ta/La ratio cannot be given because of the very low level of concentrations of these elements in these samples; nevertheless, this value is definitely different from the chondritic value of (1) characteristic of oceanic basalts with slight, or no, rare-earth-enriched distributions and is probably close to the value 0.5 found in “typically depleted” oceanic tholeiites (Bougault and Treuil, 1980). In this respect the tholeiite recovered in Hole 487 is similar to tholeiites recovered at 22°N (Bougault et al., 1978) and 25°N (Joron et al., 1979) in the North Atlantic, at 9°N on the East Pacific Rise and Siqueiros fracture zone (Joron et al., 1980), and at 21°N during the French-American submersible dives and during DSDP Leg 65 (Cambon et al., in press).

The present data presented will be compared with other data from the Central America Trench Leg 67 in a forthcoming volume.

REFERENCES

- Bougault, H., Cambon, P., Corre, O., et al., 1979. Evidence for variability of magmatic processes and upper mantle heterogeneity in the axial region of the Mid-Atlantic Ridge near 22° and 36°N. *Tectonophysics*, 55:11–34.
- Bougault, H., Joron, J. L., and Treuil, M., 1979. Alteration, fractional crystallization, partial melting, mantle properties from trace elements in basalts recovered in the North Atlantic. In Talwani, M., Harrison, C. G., and Hayes, D. E. (Eds.), *Deep Drilling Results in the Atlantic Ocean: Ocean crust: Maurice Ewing Series 2, A.G.U. Geodyn. Proj. Scientific Rept.*, 48:352–368.
- Bougault, H., and Treuil, M., 1980. Mid-Atlantic Ridge: zero-age geochemical variations between Azores and 22°N. *Nature*, 286 (No. 5770), 209–212.
- Bougault, H., Treuil, M., and Joron, J. L., 1978. Trace elements in basalts from 23°N and 36°N in the Atlantic Ocean: fractional crystallization, partial melting and heterogeneity of the upper mantle. In Melson, W. G., Rabinowitz, P. D., et al., 1978. *Init. Rept. DSDP, 45*: Washington (U.S. Govt. Printing Office), 493–506.
- Cambon, P., Joron, J. L., Bougault, H., et al., in press. Leg 65: East Pacific Rise—typical oceanic crust depleted in hygromagmaphile elements. In Robinson, P., Lewis, B. T. R., et al., *Init. Repts. DSDP, 65*: Washington (U.S. Govt. Printing Office).
- Hawkins, J. W., Jr., 1977. Petrologic and geochemical characteristics of marginal basin basalts. In Talwani, M., and Pitman, W. C., III (Eds.), *Island Arcs, Deep-Sea Trenches and Back-Arc Basins: Maurice Ewing Series 1*: Washington (American Geophysical Union), pp. 355–366.
- Joron, J. L., Bollinger, C., Quisefit, J. P., et al., 1979. Trace elements in Cretaceous basalts at 25°N in the Atlantic ocean: alteration, mantle compositions and magmatic processes. In Donnelly, T.,

Francheteau, J., Bryan, W., Robinson, P., Flower, M., Salisbury, M., et al., *Init. Repts. DSDP*, 51, 52, 53, Pt. 2: Washington (U.S. Govt. Printing Office), 1087-1098.

Joron, J. L., Briquieu, L., Bougault, H., et al., 1980. East Pacific Rise, Galapagos spreading center and Siqueiros fracture zone, Deep Sea Drilling Project Leg 54: hygromagphile elements—a com-

parison with the North Atlantic. *In* Rosendahl, B. R., Hekinian, R., et al., *Init. Repts. DSDP*, 54: Washington (U.S. Govt. Printing Office), 725-735.

Sigurdsson, H., and Schilling, S. G., 1976. Spinels in Mid-Atlantic Ridge basalts: chemistry and occurrence. *Earth Planet Sci. Lett.*, 29:7-20.

Table 2. Microprobe analyses of minerals from Sample 487-20-1, 55-58 cm.

Analysis	Olivines						Spinels		
	1	2	3	4	5	6	7	8	9
SiO ₂	40.79	40.57	40.49	40.47	41.03	40.09	0.48	0.98	0.60
TiO ₂	0.00	0.00	0.02	0.00	0.00	0.02	0.37	0.33	0.29
Al ₂ O ₃	0.07	0.08	0.04	0.01	0.00	0.03	32.99	32.88	31.00
Cr ₂ O ₃	0.03	0.00	0.00	0.07	0.15	0.00	33.51	32.90	33.38
FeO	10.86	10.72	10.41	10.97	10.93	14.20	15.41	15.72	17.11
MnO	0.17	0.27	0.21	0.03	0.20	0.23	0.00	0.31	0.07
MgO	48.51	47.39	48.41	47.37	47.48	45.01	17.04	16.74	16.18
CaO	0.31	0.31	0.39	0.32	0.41	0.38	0.06	0.18	0.38
Na ₂ O	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.07	0.00
K ₂ O	0.00	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.00
Total	100.74	99.34	99.97	99.26	100.23	99.97	99.88	100.11	99.01
FM	0.113	0.115	0.110	0.115	0.116	0.152	0.273	0.281	0.293

Analysis	Pyroxenes				Plagioclases				
	10	11	12	13	14	15	16	17	18
SiO ₂	48.41	48.04	47.17	47.13	47.14	51.58	49.27	49.97	51.43
TiO ₂	1.90	1.87	0.10	0.00	0.00	0.00	0.02	0.09	0.02
Al ₂ O ₃	6.27	5.22	33.06	33.20	33.31	29.74	31.63	30.83	29.57
Cr ₂ O ₃	0.28	0.22	0.00	0.00	0.00	0.03	0.11	0.01	0.00
FeO	8.96	11.59	0.21	0.30	0.26	0.56	0.50	0.72	0.76
MnO	0.10	0.32	0.00	0.00	0.00	0.00	0.01	0.00	0.00
MgO	12.27	11.36	0.21	0.17	0.19	0.34	0.26	0.46	0.45
CaO	21.55	20.63	17.26	17.24	17.23	14.18	15.52	14.81	14.16
Na ₂ O	0.22	0.36	1.78	1.63	1.52	3.19	2.66	2.81	3.57
K ₂ O	0.06	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.03
Total	100.02	99.61	99.80	99.67	99.65	99.62	99.98	99.72	99.99
Ca	47.2	45.1							
Mg	37.3	34.6							
Fe + Mn	15.5	20.3							
Ca			84.2	85.4	86.3	71.1	76.3	74.4	68.5
Na			15.8	14.6	13.7	28.9	23.7	25.5	31.3
K			0.0	0.0	0.0	0.0	0.0	0.1	0.2

Note: All analyses have been obtained with a Camebax automated microprobe (Microsonde Ouest, Brest), working conditions 15 kV, 10-12 nA, counting time 6 s. Concentrations lower than 0.1% are not considered representative. Total iron expressed as FeO. *Olivines*: 1.2 (core and rim of a 400- μ m phenocryst); 3.4 (core and rim of a 300- μ m phenocryst); 5.6: groundmass. *Spinels*: 7.8 (core and rim of a 20- μ m crystal); 9: small crystal (5 μ m). *Pyroxenes*: 10, 11 (groundmass). *Plagioclases*: 12-15 (core-to-rim zonation of a 150- μ m phenocryst); 16-18: microlites.

Table 3. Trace element data (ppm), Hole 487.

Sample (interval in cm)	Sc	Ti	V	Cr	Mn	Fe	Y	Zr	Nb	Sb	Cs	Ba	La
	NA	XRF	XRF	XRF	XRF	XRF	XRF	XRF	XRF	NA	NA	NA	NA
20-1, 55-58	34.0	5040	236	451	1084	70605	26	48	0.3	0.03	0.02	5.2	0.75
20-1, 72-78	33.9	5160	255	461	1239	73553	27	56	0.6	0.20	0.18		0.80
20-1, 82-89	33.4	5040	237	447	1084	68098	26	44	0.4	0.08	0.12		0.83

Sample (interval in cm)	Ce	Co		Ni		Zn	Rb	Sr	Eu	Tb	Hf	Ta	Th
	NA	XRF	NA	XRF	NA	XRF	XRF	XRF	NA	NA	NA	NA	NA
20-1, 55-58		44	45	138	144	62	0.4	54	0.81	0.47	1.07	0.033	0.013
20-1, 72-78		45	45	119	127	61	4.9	56	0.72	0.48	1.17	0.029	0.022
20-1, 82-89	1.6	46	46	129	136	60	3.1	56	0.66	0.43	1.16	0.028	0.042

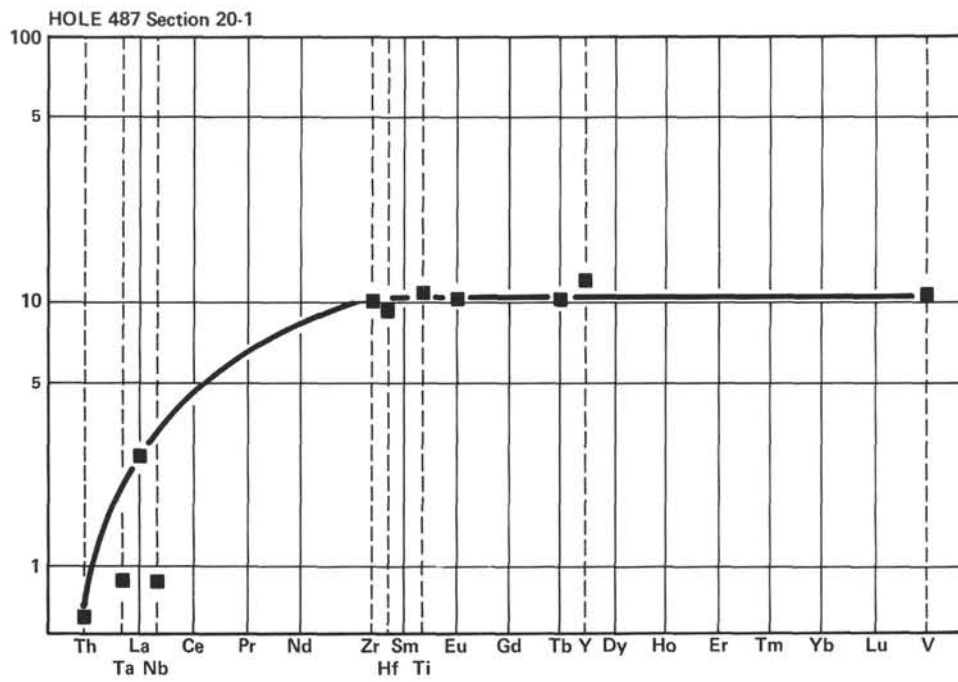


Figure 1. Hole 487: extended rare earth diagram showing the depleted character of the basalts recovered in this hole.